High-Frequency Electromagnetic Impedance Measurements for Characterization, Monitoring, and Verification Efforts

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RESEARCH OBJECTIVES

Noninvasive, high-resolution imaging of the shallow subsurface is needed for delineation of buried waste, detection of unexploded ordinance, verification and monitoring of containment structures, and other environmental applications. Electromagnetic (EM) measurements at frequencies between 1 and 100 MHz are important for such applications, because the induction number of many targets is small and the ability to determine the dielectric constant (in addition to the electrical conductivity) of the subsurface is possible. Earlier investigators were successful in developing systems for detecting anomalous areas, but no quantifiable information was accurately determined. For high-resolution imaging, accurate measurements are necessary, so that field data can be mapped into the space of the subsurface parameters. The objective of this project is to develop a noninvasive method for accurately mapping the electrical conductivity and dielectric constant of the shallow subsurface, using the EM impedance.

APPROACH

EM impedance, the ratio of electric to magnetic field, can be used to map subsurface electrical properties without the exact knowledge of the transmitter signal. A prototype 30 MHz high-frequency impedance (HFI) system was originally assembled using off-the-shelf components, including a magnetic dipole transmitter as well as electric and magnetic antennae. The system was tested in known areas against theoretical predictions (Lee and Becker, 2001), thereby verifying the utility of the EM impedance for shallow subsurface application. The test was focused on mapping only the electrical conductivity because the frequency was limited to 30 MHz. To improve data quality and to include the capability of mapping dielectric constants, we began modifying the HFI system by miniaturizing the transmitter and receiver electronics and implementing fiber optics communication.

ACCOMPLISHMENTS

Success in achieving the overall objective of the HFI system depends on the accuracy of field measurements, especially in the electric field. All electronic components have been miniaturized and repackaged, and communication is now done via optical fibers. The other important improvement for the acquisition system has been the replacement of the lock-in amplifier with the HP network analyzer. This allows much wider operating bandwidth for the HFI system, well beyond 100 MHz with greatly improved efficiency (Lee et al., 2002). Along with the hardware, we developed a one-dimensional inversion scheme, INVEM1D, in which the electrical conductivity and dielectric constant of an N-layered earth are simultaneously inverted. The key development has been the successful implementation of the analytically evaluated sensitivity function to the inversion code.

SIGNIFICANCE OF FINDINGS

The improved HFI system can be used to map shallow subsurface electrical conductivity and the dielectric constant simultaneously.

RELATED PUBLICATIONS

Lee, K.H., and A. Becker, High-frequency electromagnetic impedance measurements for characterization, monitoring and verification efforts. Interim Report, Project #60328, U.S. DOE, 2001.

Lee, K.H., A. Becker, and H.-W. Tseng, High-frequency electromagnetic impedance measurements for characterization, monitoring and verification efforts. Annual Report, Project #73776, U.S. DOE, 2002.

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